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AIRMASS DEPENDENCE OF THE DOBSON TOTAL OZONE MEASUREMENTS

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ABSTRACT

For many years the airmass dependence of total ozone measurements at Belsk has been observed to vary noticeably from one day to another. Series of AD wavelength pairs measurements taken out to high airmass were analysed (Degórska and Rajewska-Więch, 1989) and compared with the two parameter stray light model presented by Basher (1982).

The analysis extended to the series of CD measurements indicates the role of atmospheric attenuation in appearing the airmass dependence. The minor noon decline of total ozone has been observed in the CD measurement series similarly as in those of the AD wavelength pairs. Such errors may seriously affect the accuracy of CD measurements at high latitude stations and the observations derived in winter at middle latitude stations.

1. INTRODUCTION

The total ozone in middle and high latitudes still continue to decrease. With growing concern of this, it has become increasingly important to have high quality Dobson records of measurements ensuring that no real changes in total ozone would be masked by experimental uncertainty. Special attention should be given to problems which can affect trends in ozone derived from the data taken by means of Dobson instruments at large solar zenith angles. This particularly concerns the winter trends in middle and high latitudes.

In this study, attention has been given to the question of stray light in the Dobson instruments. The "stray light", as a general term, describes the stray radiation scattered by the atmosphere in the instrument's field of view as well as the unwanted radiation scattered within the instrument (Basher, 1982). Usually this effect is not large but it may be significant when we are looking for trends, especially in middle and high latitudes in winter. It is known that the stray light effect varies noticeably from instrument to instrument (Olafson and Asbridge, 1981; Basher, 1982). Also Brewer instruments exhibit the airmass dependence.

2. COMPARISON OF MODEL AND EXPERIMENTAL DATA

In the light of the above, it seems worthwhile to test the spectrophotometers for stray light. One of the methods is to take series of observations on the rising or setting Sun and to compare the results with a stray light model (Basher, 1982).

For Basher's model the stray light is defined by the two parameters: R_o which is reported to range from 10^{-5} to 10^{-3}, depending (inversely) on the quality of the instrument's stray light rejection, and a, the atmosphere's relative attenuation coefficient of the stray light band to the desired band, which ranges from about 0.7 to 1.2, depending on the ozone amount. Stray light affects the determination of extraterrestrial constant of Dobson instruments. Errors resulting from the non-linearity of Langley method measurements (the log intensity ratio versus μ) used to establish the absolute instrument calibration (the reference one, in practice) were studied by Basher for his stray light model (1982). The equation for ΔX, the resulting error in the ozone measurement, is:

$$\Delta X = \frac{-1}{\mu\Delta\alpha}(\Delta ETC + \log(1 + R_o 10^{\mu a}))$$

where: $\Delta\alpha$ is the Dobson bandpair's ozone absorption coefficient and the Basher stray light model. Calculations have been made for various values of model parameters. The values of R_o parameter were selected here as those which are close to the value of the Belsk Dobson instrument. The values of μ_1 and μ_2 were taken as 1.0 and 2.5, respectively. Comparing the top and bottom parts of Fig. 1 one can see that for instruments with the same R_o parameter value and for the same attenuation parameter a, the errors in CD ozone measurements are greater than those in AD measurements.

At greater values of the parameter a or R_o, the model of stray light shows that the resulting ozone measurement errors can be large enough to cause a significant underestimation of ozone amount. Also, the increased error at low airmasses may result in seasonal variation in noon ozone values, particularly in middle latitudes. Under not very good atmospheric conditions and for instruments of low quality, the smallest X_{AD} and X_{CD} errors are found at $\mu = 2.0$. This will result in noon values that in summer are lower than morning and afternoon values, and that in spring and in autumn are higher.

The measurements taken with the Belsk instrument have been compared to the calculated model values and a selection of results is given in Fig. 2 a,b,c,d. The main features of the plots are:

1. Similarly as for X_{AD} measurements, the μ dependence of X_{CD} values varies significantly from one day to another, depending on the value of atmospheric parameter a.

2. In every case, the values of parameter a for X_{CD} measurement series are found to be less than for X_{AD}.

3. Similarly as for X_{AD} measurement series (Degórska and Rajewska-Więch, 1989), the values of parameter a for X_{CD} measurement series do not show the expected dependence on the total ozone.

4. The X_{CD} measurement errors are not found to be less than those of X_{AD} measurement series; this may indicate that the ozone measurements disturbing factor is probably not sulfur dioxide which causes more strongly overestimated X_{CD} values as compared to X_{AD} (Komhyr and Evans, 1980).

3. CONCLUDING REMARKS

Comparison of the model (Basher, 1982) and experimental data from the Belsk station gives a strong evidence for the importance of stray light in the Dobson instruments. The resulting ozone measurement errors are estimated to reach several percent, depending on the quality of the instrument, atmospheric and operating conditions. This is of particular importance for the reliability of ozone data produced at the middle and high latitude stations.

It would be desirable to perform a similar analysis of the total ozone measurement series taken with numerous instruments located at various latitudes and air pollution conditions.

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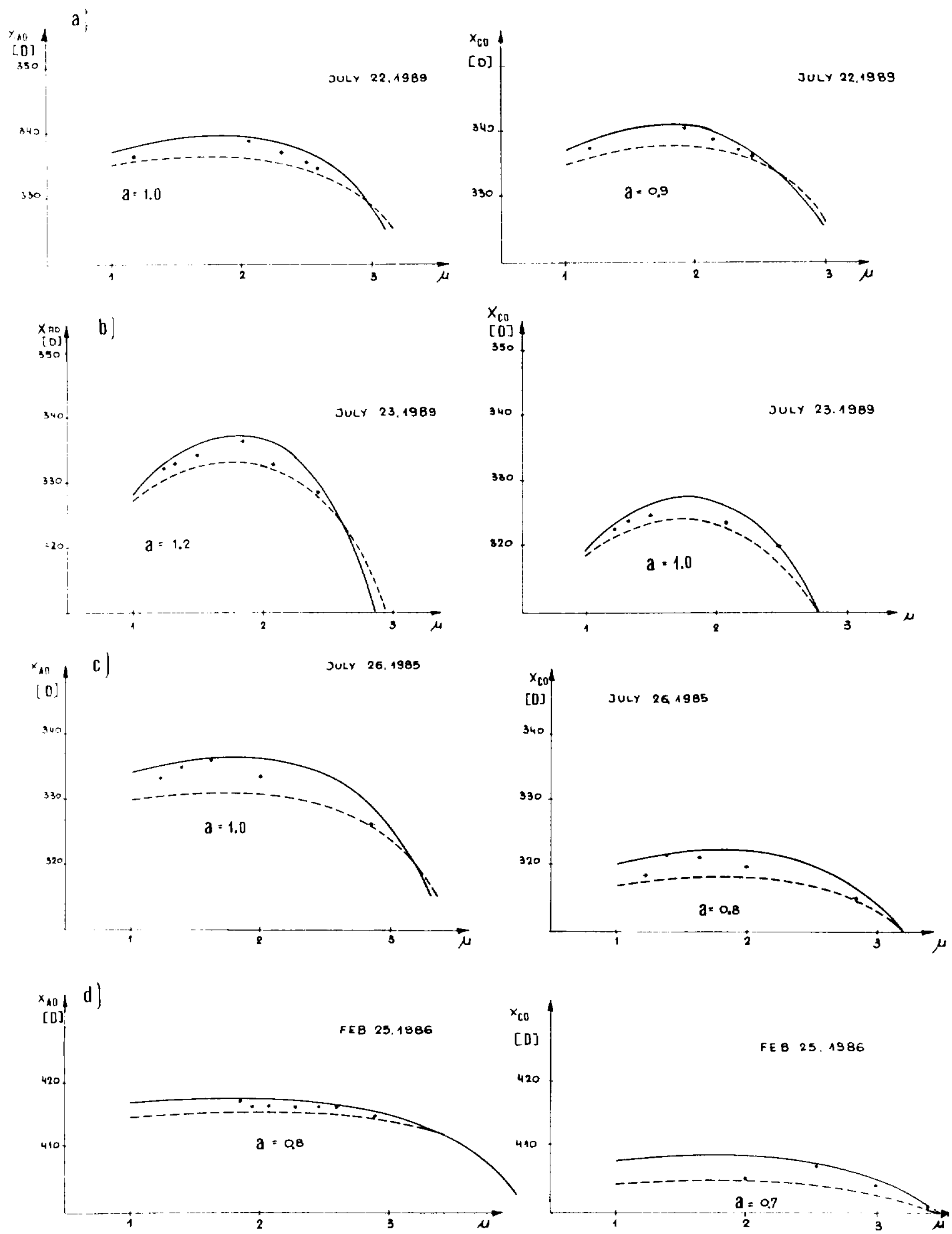

Fig. 2 a, b, c, d. Comparison of experimental data with stray light models:

——— Ro = $10^{-3.8}$; - - - Ro = $10^{-4.0}$

$$\Delta ETC = \frac{1}{\mu_2 - \mu_1} \log \frac{(1 + R_o 10^{\mu_2 a})^{\mu_1}}{(1 + R_o 10^{\mu_1 a})^{\mu_2}}$$

is the error in extraterrestrial constant, μ_1 and μ_2 are the μ values which determine the straight line used to derive the ETC by the Langley extrapolation.

Series of AD wavelength pair measurements taken out to high airmass at Belsk were analysed (Degórska and Rajewska-Więch, 1989) in terms of the Basher approach. Their main results suggested that:

1. the Belsk instrument was of quality close to that typical for most Dobson spectrophotometers,

2. the stray light level was enhanced when the atmospheric transparency values decreased.

In this study the analysis has been extended to the series of the CD wavelength pair measurements. Observations of this kind are recommended (Komhyr, 1980) to be made on direct sun in the μ range of 2.4 to 3.5 (the AD DS observations at $1.15 < \mu < 3.0$), being useful primarily at middle and high latitude stations at the times of the year when the sun is low in the sky.

Figure 1 presents variation of ozone measurement error XAD and XCD as a function of airmass μ, as calculated by

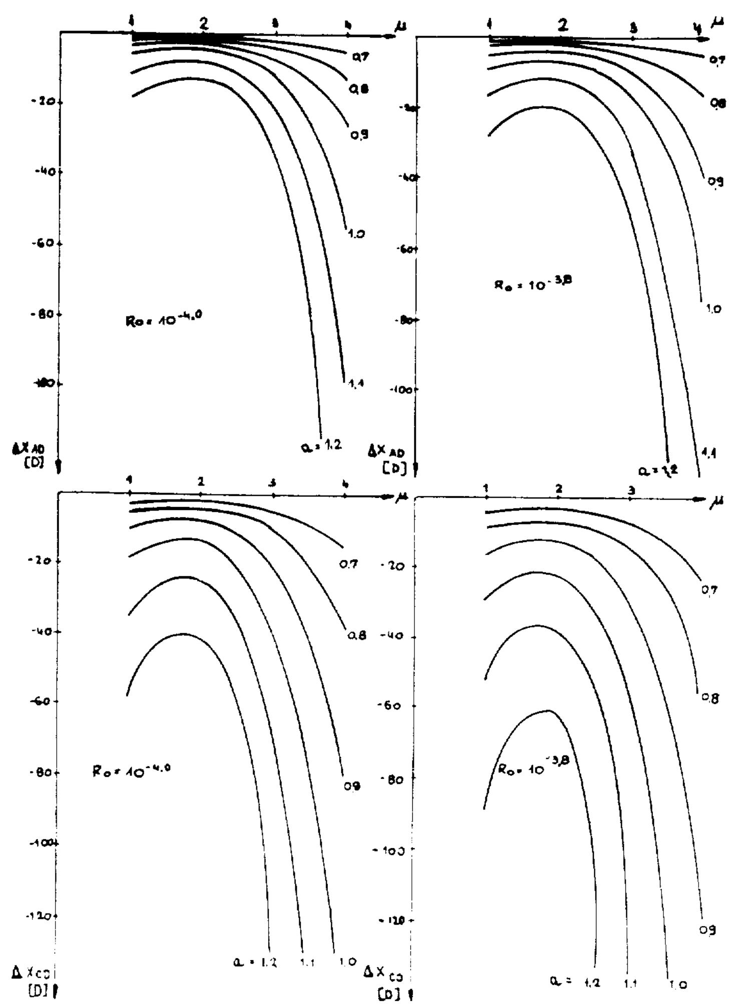

Fig.1 Variation of ozone measurement errors XAD and XCD as calculated by the Basher stray light model; $\mu_1 = 1$, $\mu_2 = 2.5$

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